SYSTEM AND METHOD FOR ELECTRIC FIELD SENSING OF A VEHICLE MOBILITY ACCESS DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/510,937, filed October 14, 2003.

FIELD OF THE INVENTION

[0002] The invention relates to sensing physical objects, and more specifically the present invention relates to a system and method for sensing the presence of an object on a mobility access device.

BACKGROUND OF THE INVENTION

[0003] Safety systems for vehicle mobility access devices such as wheelchair lifts and ramps used with buses, vans, minivans and the like are well known, and have been employed to ensure the well being of mobility-challenged users for many years. Numerous safety systems for such vehicle mobility access devices have been proposed and implemented that include mechanical, electrical, or electromechanical sensing, or a combination thereof. However, existing sensing devices, systems and methods typically require a trade-off between a desired sensitivity range and accurate calibration. Thus, the operating range of existing safety systems often comes at the expense of the systems' sensitivity of discrimination.

[0004] As is known, for a sensor to be able to recognize an object as an obstruction on a vehicle mobility access device, such as on the platform of a wheelchair lift, the sensor must be sensitive to discriminate between the presence of a real obstruction (e.g., a user or mobility aid such as a wheelchair), and a perceived (e.g., sensor noise or latency) or unimportant obstruction (e.g., a piece of trash or debris). To discriminate between the foregoing types of obstructions, sensors (and/or systems interpreting sensor data) have set thresholds that typically necessarily exclude specific sensing ranges. For example, a load-sensing disable switch or the like is generally well known for use with vehicle wheelchair lifts so that the lift platform cannot fold closed (i.e., stowed) if there is more than a predetermined weight (e.g., 30-80 lbs.) on the platform.

[0005] Sensing systems for vehicle mobility access devices having a hydraulic drive may include the use of pressure sensing devices, transducers and the like to detect a load by sensing hydraulic fluid pressure in excess of a predetermined hydraulic pressure threshold, or otherwise discriminating real-time changes of fluid pressure. Such load sensing switches, sensors and systems must be routinely maintained and calibrated to ensure proper operation. Also, such switches and sensors are prone to wear and failure over time, and may be difficult and/or expensive to repair or replace. For example, replacement or repair of a transducer in a hydraulic power unit's manifold may require the removal and/or replacement of the entire unit.

[0006] As control systems for vehicle mobility access devices such as wheelchair lifts and ramps are becoming more closely integrated and communicative with vehicles' control systems, it is desirable to implement an electronic sensing system that can seamlessly operate with the existing control systems. For example, an electronic controller for a vehicle wheelchair ramp may communicate with the OEM vehicle controller to coordinate vehicle door opening, deployment of the ramp, and kneeling of the vehicle. One or more of the controllers may receive output signals from various sensors for comparison to known sensor output profiles. As is relatively well known, the OEM vehicle controller may cooperate with current, voltage, or other sensors and timers for detecting the presence of obstructions or loads relative to closing of the door. Further, the ramp controller may store a baseline or known profile relative to the operation of a ramp motor to discriminate the presence of an object on the ramp (i.e., the ramp motor input current required to stow a ramp with an object thereon is typically greater than the ramp motor input current required to stow a ramp without an object thereon, and/or the time to fully stow a ramp with an object thereon is typically greater than the time required to stow a ramp without an object thereon). Over time, however, due to mechanical wear and other environmental factors, the programmed current and time thresholds will need to be reset or otherwise adjusted to perform accurate sensing.

[0007] Therefore, in view of the foregoing, it is desirable to provide an adaptive and robust sensing system for use with a vehicle mobility access device controller. Further, the sensing system may provide for self-calibration during known timeframes or instances when the mobility access device is unoccupied. Thus, by employing such a sensing system, a sensing method may be achieved where sensing ranges are not excluded.

SUMMARY OF THE INVENTION

[0008] An embodiment provides an electric field proximity sensing system for detecting the presence of an object on a vehicle mobility access device such as a wheelchair lift or ramp. One or more electrodes are coupled to surfaces of the device and the electrodes are electrically excited to provide electric fields proximate the surfaces. The one or more electrodes are linked to an electric field imaging module that communicates with an electronic controller. The electric field imaging module operates to drive the electrodes and receive inputs therefrom by sampling the electrodes' fields for discriminating changes or disturbances to the fields due to objects therein. The one or more electrodes may be selected sequentially by the module to detect an object in various locations and/or to determine an object's size, shape, and distance from the electrodes. When an object is sensed, the controller can disable a mobility access device or vehicle function so that user injuries are prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention is described with reference to the accompanying figures which illustrate embodiments of the present invention. However, it should be noted that the invention as disclosed in the accompanying figures and appendices is illustrated by way of example only.

[0010] FIG. 1 is a perspective view of an exemplary wheelchair lift for use with the subject sensing system and method, showing the general arrangement of components;

[0011] FIG. 2 is a block diagram illustrating an exemplary control system including an electric field sensing subsystem;

[0012] FIG. 3 is a plan view of an exemplary electric field sensor for use with the control system of FIG. 2; and

[0013] FIG. 4. is a block diagram illustrating an exemplary method of object sensing for the exemplary wheelchair lift of FIG. 1.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0014] Referring now to the figures, and particularly FIG. 2, a control system 400 including electric field (hereinafter "EF") sensing for a vehicle mobility access device is

shown. One exemplary vehicle mobility access device 10 for which the control system 400 may be employed is illustrated in FIG. 1 to be a parallelogram-type wheelchair lift, however, the control system 400 may be used with other types of lifts, ramps and other devices known in the art that assist mobility-challenged individuals to access a vehicle. For example, the control system 400 apparatus may be used in connection with a foldable or otherwise extendable ramp known in the art. As shown, an inboard/outboard orientation known in the art is indicated by arrows IB/OB, with the inboard direction being towards the vehicle V or inward, and the outboard direction being away from vehicle V or outward. As is known, the vehicle mobility access device 10 is mounted to the vehicle floor F proximate a door D to assist a mobility-challenged person in a wheelchair or using another mobility device such as a scooter, walker, or the like to enter the vehicle interior. As illustrated, the device 10 is located on the right side of the vehicle V, but may alternatively be located elsewhere, for example, on the left side of the vehicle V or at a vehicle rear door.

[0015] As can be appreciated from FIG. 1, a person may be loaded into the vehicle V by way of the lift platform 12, which may be unstowed or deployed from within the vehicle V, lowered to the ground level (as shown), and then raised to the vehicle doorway floor level F (hereinafter referred to as the transfer level or threshold). The inboard barrier 70 acts as a bridgeplate to mate with the mobility access device's baseplate 30, which is affixed to the vehicle floor, to provide a smooth transition for a user to cross from the platform 12 inboard to the threshold area inside the vehicle V. Additionally, the inboard barrier 70 cooperates with an outboard barrier 50 and side barriers 13, 13' to frame the platform surface 17 for preventing an object from accidentally falling off the platform 12, particularly when the platform 12 is raised above the ground level. Once the user is inside the vehicle V, the platform 12 may be safely folded and stowed in the threshold area (i.e., proximate the baseplate 30).

[0016] As is known, the device 10 may become damaged if the platform 12 is stowed/folded when it is obstructed by an object thereon. Further, the device 10 may cause injury to a user occupying the platform 12 or the threshold area 30 during a stowing/folding operation. To this end, the device 10 includes a control system 400 with one or more sensors for inter alia, detecting the occupancy state of one or more locations on the device 10. As shown in FIG. 2, the control system 400 includes a controller 408. The controller 408 may be a microprocessor controller, microcontroller, PLC, or other controller known in the art for

controlling the operation of the mobility access device 10. Controller 408 cooperates with OEM vehicle control module 406 for overall control, coordination and synchronization of OEM vehicle functions/subsystems such as door motor 420, key control 412, and interior controls 304 with an installed mobility access device 10 (FIG. 1) including, for example, a wheelchair lift motor 418 to facilitate vehicle handicapped accessibility. Controller 408 communicates with the OEM standard control module 406 via communications bus 405. Since wheelchair lift motor 418 is an after-market system, it typically cannot communicate with OEM control module 406. To this end, the controller 408 may monitor signals from the OEM control module 406 via communications bus 405 and relays such OEM signals to the various aforementioned OEM vehicle functions to synchronize access operations. Although the OEM subsystems such as door motor 420, key control 412 and interior controls 304 are shown as linked, coupled or otherwise in direct communication with the controller 408, such OEM subsystems may alternatively be linked to the OEM control module 406.

[0017] In the foregoing description and the following exemplary scenario the controller 408 controls and coordinates OEM and mobility access device functions to provide access to a vehicle, but the controller 408 may only operate to control the mobility access device 10. Referring to FIGs. 1 and 2, a mobility-challenged user outside a vehicle V may press a button on a hand control, key-fob or keyless-entry remote 200 to access the vehicle V by way of the movable lift platform 12. The remote 200 may transmit a radio frequency (RF) signal, which is received at antenna 402 and processed by receiver 404. Alternatively, the remote 200 may be coupled to the controller 408 for wired communication therebetween. The signal or communication from the remote 200 may be a request from the user to perform one or more OEM or mobility access device functions, including but not limited to: start the vehicle ignition, unlock and open the vehicle door and deploy the lift 10. The receiver 404 relays the access request to the controller 408 which then requests that OEM controller 406 unlock doors via key control 412, and open a door such as a power sliding door with door motor 420. After controlling and coordinating the foregoing OEM functions, controller 408 may then control deployment and lowering of the wheelchair lift 10 by operating lift platform motor 418. The user accesses the lowered lift platform 12, and is subsequently lifted from ground level to the vehicle door threshold height F by actuating the remote 200.

[0018] As previously mentioned, the control system 400 includes EF sensors. To this end, EF electrodes 422 (FIG. 2) are arranged on one or more surfaces of the wheelchair lift 10 and the controller 408 includes an EF imaging module 416 that communicates with the electrodes 422. As shown, the EF imaging module 416 is integrated into the controller 408, but the module 416 alternatively may be external to the controller 408 and linked thereto for communication. As will be discussed in further detail hereafter, the controller 408 communicates with the EF imaging module 416 for receiving an output therefrom indicative of the presence of an object in or proximate to an electric field generated by the EF imaging module 416 in cooperation with the EF electrodes 422. The communication between EF imaging module 416 and controller 408 may follow various protocols including, but not limited to, constant communication, and query/response-type communication wherein the EF imaging module 416 does not send any signals/data to controller 408 unless it is polled, activated or otherwise asked to. The module 416 may be an integrated circuit (IC) or other device operative to generate an electric field and detect an object therein. One exemplary EF imaging module 416 is the 33794 IC available from Motorola, Inc, although other suitable EF imaging modules or devices may be substituted. The 33794 is intended to be used where an object's size and/or proximity are to be determined. This is done by placing one or more electrodes 422 in locations where object sensing is desired.

[0019] The module 416 may include an oscillator, multiplexer, rectifier, and filtering. The oscillator generates a waveform, such as a sine wave, which is optimized for very low harmonic content. The waveform is output to energize an electrode 422 via the multiplexer, which simultaneously samples the electrode's generated field. The sampled field is rectified to DC, filtered, multiplied and offset to increase sensitivity. Variations in DC voltage of the sampled field indicate an object brought into or out of the electrode's field. The proximity of an object to an electrode 422 can be determined by the increase in effective capacitance as the object gets closer to the electrode 422 and modifies the electric field between the electrode 422 and surrounding electrically common objects. The shape and size of an object can be determined by using multiple electrodes 422 over an area and observing the capacitance change on each of the electrodes 422. As is known, the controller 408 may include a memory or storage means for storing received communications from the module 416, such as for example, a baseline electrode signal as discussed hereafter in further detail.

[0020] One exemplary arrangement of EF electrodes 422 for object sensing in the vehicle threshold area of a wheelchair lift is illustrated in FIG. 3. As can be appreciated, the electrodes 422a-d may be adapted to substantially correspond with various locations/surfaces on the mobility access device 10 for which object detecting is desired. For example, one or more electrodes 422 may be coupled to the lift platform surface 17, the inboard and outboard rollstops 70, 50 and the baseplate 30. In this way the controller 408 may check for occupancy of various locations on the lift 10 before actuating a lift operation or function such as raising, lowering, deploying and stowing the lift platform 112. As can be appreciated, one or more electrodes 422 may be coupled to one or more surfaces of a ramp such as one or more movable ramp sections, side barriers and inside the vehicle, for example within or proximate to the threshold area. As illustrated in FIG. 3, each of the electrodes 422a-d may comprise a wire or conductor in a zigzag pattern within a rectangular or otherwise geometric or curvilinear area to provide an electrical field with a known shape and volume. EF electrodes 422 may be wire such as 30 gauge, metallic film material such as mylar, flex circuits or the like known in the art. The EF electrodes 422a-d may be attached to the lift using adhesive or other attachment means known in the art such as fasteners including clips or ty-wraps. As can be appreciated from the foregoing, in one exemplary embodiment and use of the system 400 when the platform 112 is at the transfer level F, the controller 408 may communicate with the module 416 to check the electric fields generated by electrodes 422 on the platform surface 17 and inboard barrier/rollstop 70 to prevent accidental tipping of a wheelchair occupant before the barrier 70 is raised in anticipation of lowering the platform 12. Further functionality of the system 400 is described hereafter.

[0021] The one or more EF electrodes 422 in communication with EF imaging module 416 emit one or more electric fields with known electrical characteristics. The EF imaging module 416 is able to selectively energize one of several connected electrodes 422 in response to controller 408. As previously mentioned, the EF imaging module 416 includes a receiver multiplexer which simultaneously allows for sampling of the electric field being emitted by the selected electrode 422. If an object is within an emitted electric field of an electrode 422, the EF imaging module 416 discriminates the object's presence due to a change in effective capacitance as the object gets closer to the electrode 422 and modifies the electric field between the electrode 422 and surrounding electrically common objects. The object presence can be observed by the capacitance change on each electrode 422. Aside from an object's

presence, the EF imaging module 416 may also detect the size and shape of an object as well as its distance from one or more electrodes. The shape and size of an object can be determined by using multiple electrodes over an area and observing the capacitance change on each of the electrodes. The absence of change in electrode capacitance would be indicative of electrodes that have nothing near them, while those that do show a capacitive change have a part of the object near them. Similarly, a large change in an electrode's electric field may correspond to a large object, while a small change in the electric field may correspond to a small object.

[0022] In FIG. 4, a flow chart illustrating an exemplary method for EF sensing of an object on a wheelchair lift is shown. Although the exemplary method refers to a lift, the term lift is intended as non-restrictive such that the exemplary method may apply for lifts such as parallel arm lifts, under-vehicle and stepwell lifts known in the art, as well as wheelchair ramps and other mobility access devices. Starting at block 100, a wheelchair lift is triggered for lift deployment by a user or lift operator pressing a button or activating a switch inside or outside the vehicle. Depending on the lift configuration, it may be folded or stowed inside or underneath the vehicle. The request to deploy the lift is received at the controller 408 in block 110, and the controller 408 communicates or otherwise cooperates with control module 406 to unlock and open a door and subsequently deploy the lift. Alternatively, if the door is already open, the lift controller actuates a lift motor, pump or the like to unfold/deploy the lift and positions the platform surface at the egress level of the vehicle. The controller 408 recognizes when the lift is fully deployed by using time thresholds, sensed lift motor current measurements, or other sensing means such as microswitches or the like and instantly energizes one or more EF electrodes before the platform can be occupied. By energizing the EF electrodes at the instant that the lift is fully deployed, the controller 408 in communication with the EF imaging module 416 may calibrate the EF electrodes as shown in block 120. The electric fields generated at the instant the lift is fully deployed serve as baseline electric fields since there can be no objects on the lift at that very instant.

[0023] In block 130 the user accesses the lift platform and requests lift lowering. The lift lowering request is received at the controller 408, which may queue or otherwise delay the lowering request, and activates the appropriate one or more EF electrodes 422 via the EF imaging module 416 in block 140 to determine if the user is located on the lift platform so that the lift can be lowered safely. For example, appropriate EF electrodes to energize when a lift

lowering is requested could be located on one or more of the lift baseplate 30, inboard rollstop 70, platform surface 17 and outboard rollstop 50. In this way, if a user accidentally requests lift lowering before being safely situated on the platform 12, the EF imaging module 416 will energize the one or more electrodes, and sample the electric fields before the controller 408 acts to move the platform 12. The EF imaging module 416 selectively energizes the electrodes 422 and compares the sampled electric fields to the baseline electric fields to discriminate a change in one or more fields indicative of an object therein or proximate thereto. The EF imaging module 416 communicates the EF electrode's field change to the controller 408 which prevents lowering of the lift in block 150. The controller 408 in block 150 may also discard the queued lowering request and indicate to the user that it is unsafe to lower the lift by actuating a visual or audible alarm or activating another indicating means. The user may then adjust their position on the lift, or the lift operator may move the obstruction and again request lift lowering at block 130. In block 140, if the EF imaging module 416 energizes the one or more electrodes and determines that the sampled electric fields do not differ from the baseline electric fields or that the sampled electric fields are not otherwise indicative of an unsafe condition, the controller 408 is so notified by the EF imaging module 416. The controller 408 in block 160 sends a signal to the lift motor, the lift is lowered to ground level and the user then exits the lift platform.

[0024] In block 170 the wheelchair lift is deployed and waiting to be raised from the ground level. A user enters the lift and initiates a lift raise request in order to access the vehicle. The user-initiated lift raise request is accomplished by actuating a button, switch, or the like on the wheelchair lift. Alternatively, a lift operator such as the vehicle driver may actuate a button, switch, or the like inside or outside the vehicle. The controller 408 having received the lift raise request, queues or otherwise delays a physical response to the raise request and activates the appropriate EF electrodes via the EF imaging module 416 in block 180 to determine if the user is located or otherwise positioned on the lift platform so that the lift can be raised safely. The EF imaging module 416 selectively energizes the electrodes and compares the sampled electric fields to the baseline electric fields and may detect a change in one or more EF electrode fields.

[0025] For example, appropriate EF electrodes to energize when a lift raising is requested could be located on the lift rollstops 50, 70. In this way, if a user accidentally requests lift

raising before being safely situated on the platform surface 17, the EF imaging module 416 will energize the rollstops' electrodes and sample the electric fields. If an object is detected on one or more of the rollstops 50, 70 the EF imaging module 416 communicates the EF electrode's field change to the controller 408 which prevents raising of the lift in block 190. Similarly, it may be desirable to determine if an object is present in the threshold area (i.e., on the baseplate 30) so the platform 12 may be raised completely and/or stowed without injuring a person inside the vehicle near the threshold or damaging the lift. Therefore, after verifying that the user is safely situated on the platform 10, the controller 408 may communicate with the EF imaging module 416 to energize a threshold electrode and sample its electric field. If an object is detected on the threshold 20, the EF imaging module 416 communicates the EF threshold electrode's field change to the controller 408 which may prevent raising of the lift in block 190. The controller 408 in block 190 having sensed the unsafe occupation may then discard the queued raise request and indicate to the user that it is unsafe to raise the lift by actuating a visual or audible alarm or activating another indicating means. The lift user may then adjust their position on the lift or the operator may remove an obstruction from the platform 12 or threshold 30 and again request lift raising at block 170. Alternatively, in block 180, if the EF imaging module 416 energizes the appropriate electrode(s) and determines that the sampled electric field(s) do not differ from the baseline electric fields or that the sampled electric fields are not otherwise indicative of an unsafe condition, the controller 408 is so notified by the EF imaging module 416. The controller 408 in block 200 then sends a signal to the lift motor, the lift is raised to vehicle threshold level, and the user enters the vehicle.

[0026] Having entered the vehicle, the user or lift operator requests stowing of the wheelchair lift by pressing a button or activating a switch inside or outside the vehicle. By triggering lift stowage, the lift may be folded and stored inside or under the vehicle. The initiated request to stow the lift is received at the controller 408 which queues the stow request and activates the appropriate EF electrodes via the EF imaging module 416 in block 210 to determine if the user or another object is located on the lift or in the threshold so that the lift can be stowed safely. Similar to the lowering and raising operations described above, the EF imaging module 416 selectively energizes the appropriate one or more electrodes and compares the sampled electric fields to the baseline electric fields to discriminate a change in one or more electrodes' fields. The EF imaging module 416 communicates any field changes to the controller 408 which prevents stowing of the lift in block 230.

[0027] As is known, prior to a stowing operation it is desirable to ensure that no part of the lift or threshold is occupied or obstructed. As such, the controller 408 may communicate with the EF imaging module 416 to energize all lift electrodes. For example, the controller 408 communicates with the EF imaging module 416 to sequentially energize electrodes on the rollstops 50, 70, platform 12, and threshold 30. The EF imaging module 416 compares the sampled electric fields to the baseline electric fields for each electrode, and if a change is detected in any field, the field change is communicated to the controller 408 which prevents stowing of the lift. The controller 408 in block 230 may also discard the queued stow request and indicate to the user that it is unsafe to stow the lift by actuating a visual or audible alarm or activating another indicating means. The user or lift operator may then clear the obstruction and again request lift stowage. Alternatively, in block 210, if the EF imaging module 416 energizes the electrodes and determines that the sampled electric fields do not differ from the baseline electric fields, the controller 408 is so notified by the EF imaging module 416. The controller 408 in block 220 sends a signal to the stow/fold motor, the lift is stowed, and the vehicle door may be closed.

[0028] While the present invention has been illustrated by a description of various embodiments and while these embodiments have been set forth in considerable detail, it is intended that the scope of the invention be defined by the appended claims. It will be appreciated by those skilled in the art that modifications to the foregoing preferred embodiments may be made in various aspects. It is deemed that the spirit and scope of the invention encompass such variations to be preferred embodiments as would be apparent to one of ordinary skill in the art and familiar with the teachings of the present application.